Progress Energy

February 28, 2012

The Honorable Jocelyn G. Boyd
Chief Clerk/Administrator
Public Service Commission of South Carolina
101 Executive Center Drive (29210)
Post Office Drawer 11649
Columbia, South Carolina 29211

Re: Docket No. 2008-251-E

Dear Mrs. Boyd:

Pursuant to the Commission's May 6, 2009 directive in Docket No. 2008-251-E, Progress Energy Carolinas, Inc. ("PEC") submits the attached evaluation, measurement & verification ("EM&V") report for its Solar Water Heating Pilot Program. PEC is currently evaluating the recommendations provided in the EM&V report.

Very truly yours,

Len S. Anthony/mhm

Len S. Anthony
General Counsel
Progress Energy Carolinas, Inc.

LSA:mhm

Attachment

Progress Energy Service Company, LLC
P.O. Box 1551
Raleigh, NC 27602

PROGRESS ENERGY CAROLINAS

SOLAR WATER HEATING PILOT PROGRAM

FINAL REPORT

KEMA PROJECT 2294006

Contents

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EXECUTIVE SUMMARY

Progress Energy Carolinas ("PEC") initiated a Solar Hot Water Pilot Program (SWHPP) to determine the overall effectiveness of solar domestic water heating systems, when retrofitted to existing electric water heating systems in their service area. Incentives in the amount of $1,000 per household were offered to 150 households to install the solar systems. Sixty households were selected to have monitoring equipment (data loggers) installed temporarily, to provide "real world" information on the system performance. The installation of the monitoring equipment began in July 2010, and installation was complete by September 13, 2010. Initial summer data collection efforts started in August 2010, and monitoring was completed in late August 2011. Monitoring of the system was done with the solar system operational, and then again with the solar system deactivated. Comparison of the performance data with the solar system active, versus data with the solar system deactivated, provided input that was used to determine several performance values. Below is a summary of the results of this pilot program:

1. ENERGY: The average solar water heating system achieved a decrease of 2,316 total kWh in the total electric energy required for the production of hot water, as compared to an average home using an electric water heater.
2. DEMAND: The average solar water heating system achieved a decrease of 0.44kW integrated coincident peak kW demand at 8 - 9 AM during the winter months, and a decrease of 0.32 integrated coincident peak kW demand during the summer months at 4 - 5 PM.
3. INSTALLATION COSTS: The average cost to retrofit a solar water heating system for the participants is $7,271.
4. IMPACTS ON SAVINGS: The impact on the annual savings of a solar water heating system versus an electric water heater for four variables are:
    a. *Demographics* – Per the limited sample size and variation of water usage in the study no significant impact on the performance or savings could be determined...
    b. *Seasonal variations* - Solar system performance is reduced significantly during the winter months, as compared to performance during summer months.
    c. *Inlet water temperature* – The temperature of the inlet water to a water heating system varies approximately 20 ° Fahrenheit from summer to winter, and the drop in inlet water temperature requires a water heating system to use up to 50% more energy to make hot water in the winter, as compared to summer months.
    d. *Geographic location* – There is no significant impact on solar system performance or savings in North and South Carolina due to the geographical location.

PROGRAM METHODOLOGY

Overall program implementation

The purpose of the Solar Water Heating Pilot Program (SWHPP) is to determine the potential impact of a solar domestic water heating system for a typical PEC residential customer in North and South Carolina, for homes with an electric domestic water heater. Incentive funds were allocated for 150 residential PEC customers to retrofit a solar domestic hot water (SDHW) system into homes that had an electric water heater. New construction homes, and homes with non-electric water heating, were excluded from the study. Some retrofits included solar home heating systems in conjunction with their SDHW systems; although these types of systems were to be excluded, some were accepted due to an initial low participation rate in the first year of the program.

Program participants were solicited by PEC prior to the start of the program in July 2009. Participation in the program was completely voluntary, although participants were required to comply with the following restrictions:

1. The home must be an existing structure and served by PEC
2. The existing domestic water heating system must be electric
3. Participants agreed to work with PEC and its subcontractor in the instrumentation and data collection portion of the program
4. The installation contractor must be from an approved list, provided by PEC.
5. The incentive is paid only after all inspections by the local authorities having jurisdiction have completed their reviews and approvals. Typically, an approved building inspection permit was required as proof of completion of the work.
6. PEC employees are ineligible to participate in the program.

Contractors used for installing the systems were only allowed from an approved list. PEC provided minimum criteria for the contractor firms, and reviewed and approved each firm. The homeowner was responsible for the selection of the contractor, negotiation of fee, and selection of the solar system and its components.

Sixty of the 150 participants (40%) were selected for installation of temporary instrumentation to determine system performance. On July 14, 2010, customers were notified that they were selected for instrumentation of their systems. Installation of the data loggers for the customers was completed by September 13, 2010. An "event" data logger, which records when an electrical component either turns on or off, was installed on the electric water heater, and on the pump for the solar system. In addition, some homes had a temperature data logger installed on the inlet water line to the electric water heater to monitor the temperature of the water prior to entering the hot water system.

After installation, the data loggers collected data for a minimum two weeks. During this time period, the solar system was performing as the main source of hot water, and the electric water heater acted as a "backup" to the solar system, if needed. Each site was visited, and data collected from the data loggers after the minimum two weeks time. The solar system was then disabled such that all of the home's domestic hot water was produced by the electric water heater alone. After two weeks, the data was collected from the data loggers again, and the solar systems were put back into service. By review and normalization of the data, the total energy (in kWh) used by the hot water systems with the solar system in operation could be determined, as well as the total energy used by the hot water system with only the electric water heater in operation. Comparison of the energy usage for a hot water system with the solar system in operation and then with the solar system rendered inoperable provides the potential energy savings realized by the homeowner who has installed one of these systems. Data was collected for system performance for a period of one year. Data collected with the solar system off (electric water heater only) was performed in the summer/early fall, and again in the winter, to determine energy usage for home without the solar system in operation.

Details of the program implementation are provided in the following sections.

Selection of customers for instrumentation

Sixty of the maximum 150 program customers were selected to receive data loggers to monitor the performance of their solar systems. To insure that data would adequately represent the "typical" PEC residential customer, and to determine the potential impact of variables with the solar systems as well as the homeowners, the following criteria was used:

1 Geographic location

2 Type of solar water heating system

3 Type of solar collector

4 Number of occupants in home

A map showing the geographical regions of the sixty instrumented customers is provided in Appendix 1.

Geographic location was established as a criteria, assuming possible variations in system performance due to local weather (air temperature and wind). The PEC service area covers most of Eastern North Carolina, as well as the Asheville and surrounding area, and the northeastern portion of South Carolina. Of the 60 instrumented homes, 20 were selected in the Asheville area (Mountain region), 20 in the Raleigh/Chapel Hill area (Piedmont region), and 20 in the Wilmington area (Coastal region).

Two basic types of solar systems were installed under this program: (1) drainback and (2) pressurized glycol. The drainback system protects the overall solar system from freezing or overheating by draining the fluid from the collectors into a drainback tank. A pressurized glycol system does not utilize a drainback tank, and depends upon the glycol solution to mitigate freezing during the winter months. Overheating of a pressurized glycol system is addressed by either allowing the system to reject heat at night, adding an auxiliary cooling heat exchanger, or by use of a high temperature solution other than glycol (along with components capable of withstanding prolonged high temperatures above 200 ° Fahrenheit). It should be noted that although the main method of freeze protection for a drainback system is to temporarily drain the fluid from the collectors into a tank, the solution used in drainback system is often the same as a pressurized glycol system, which is a mixture of food grade propylene glycol and water. All of the systems instrumented in the Western region were pressurized glycol systems, which would appear to be favored by contractors and homeowners in that area. In the Piedmont and Coastal regions, the ratio of pressurized glycol to drainback was approximately 50%/50%. During the selection process for instrumentation, homes were considered on the basis of glycol vs. drainback systems. Simplified schematics for typical drainback and pressurized glycol solar systems are provided in Appendix 2.

Two basic types of solar collectors are being used in the PEC service area, flat plate and evacuated tube. The flat plate collector is more common than the evacuated tube design, and initial costs are less than evacuated tube collectors as well. Since the evacuated tube collector is not commonly installed, the selection of homes for instrumentation with evacuated tube collectors was a high priority.

The utilization rate and time of use of domestic hot water is a direct function of the home occupants. Therefore, during the selection process for instrumenting homes, consideration was given within each of the three geographic areas as to the number of home occupants. For simplicity, each home was identified as having 1 – 2 occupants, 3 – 4 occupants, and 5 or more occupants. Although most homes have 3 or fewer occupants, selection of homes with 4 or more occupants was considered important to provide good statistical representation of hot water usage data. However, due to the relatively low number of participants with 5 or more occupants in the home, the results for 5 – 6 occupants are considered statistically invalid.

Appendix 2 provides a comprehensive summary of household and solar system data for each of the sixty instrumented customers.

Instrumentation

As noted earlier, the purpose of this study is to determine the average energy savings (in kWh) and the demand (in kW) impact by using a solar water heating system in lieu of an electric water heater for a typical home in the PEC service area. The energy savings was determined by comparing the total hours of run time for the solar system pump (or pumps), along with the total hours of run time for the electric water heater as a back-up, to the total run hours of the electric water heater as the primary source of hot water (no solar contribution). Since the demand (in kW) for the electric water heater element and the solar pumps is constant, the total energy can be calculated by multiplying the run hours by demand (kW) to calculate the total energy (kWh). As such, a simple data logger device that records the day and time a device turns on, and the day and time the device turns off, is adequate for the purposes of this program. The utilization of flow meters or other data collection devices was not deemed necessary.

One variable that causes a change in the total energy used to heat water is the entering water temperature supplied to the hot water system. In the PEC service area, the average ground water temperature is approximately 64 degrees Fahrenheit. However, this value changes throughout the year. Also, some homes use water from a municipal water distribution system, while others use well water. A temperature data logger was used in addition to the on/off (event) data loggers to help determine the potential impact of inlet water temperature on the overall energy used to make hot water. While 20 event loggers were used in each of the three major areas, only 5 temperature loggers were used in each area, under the assumption that the inlet water temperature did not vary significantly within a given geographical area. The water temperature loggers were distributed to homes with well systems in addition to municipal water systems to determine if there is a significant variation in ground water temperatures.

Data loggers

The on/off, or event, data loggers used were Dent "MAGlogger" units. These units take advantage of the fact that current flowing through a wire will generate a local magnetic field. Therefore, whenever a pump or a water heater element turns on, a magnetic field is generated in the wire, and the data logger notes the day and time that the component turned on. Conversely, when the component turns off, the data logger notes the day and time when it is turned off. The data loggers were installed on the solar pump (or one pump if there were two pumps), and on the electric water heater power conduit or wire. The pump data logger could not be attached directly to the pump motor, as the pump motor's temperature could easily exceed 180 degrees Fahrenheit when in operation, and damage the data logger or its battery.

The data loggers have a USB interface, and data was retrieved from each data logger using a laptop computer running software provided by the manufacturer.

The inlet water temperature data logger is a HOBO model U12-006, along with a temperature probe that was placed in direct contact with the inlet water pipe, and under insulation. Unlike the event data loggers, the temperature data loggers were set to capture the inlet water temperature every 15 minutes.

Appendix 4 contains photographs of typical installations of data loggers on a solar system circulation pump (event), and electric water heater (event), and the cold water inlet line for the electric water heater (temperature).

RESULTS

The following program results are summarized below, based upon the information gathered over one year for this program.

Energy savings

The average energy savings for a homeowner using a solar domestic hot water system is 2,316 kWh per year, over the use of an electric water heater. Appendix 5 provides a summary of the energy usage for the solar pumps and electric water heater for one year. Energy usage is broken down per hour for each month of the year. The average energy savings was calculated as follows:

Energy savings, kWh = (Solar pump energy, kWh + Backup electric water heater energy, kWh)

– (Electric water heater energy, kWh)

The actual energy used by the solar pump and the backup electric water heaters was measured using the data loggers for an entire year. The solar system was turned off for a minimum two weeks in the summer/fall and then again in the winter, to determine the amount of energy the electric water heater required to provide hot water. The energy savings is the difference between the annual energy consumed by the solar water heating system minus the annual energy consumed by the electric water heater to provide hot water.

Demand impact

The average integrated demand impact of a solar domestic hot water system is:

<u>Winter</u>

Coincident peak reduction: 0.44 kW (8 – 9 AM January)

Maximum peak reduction: 0.63 kW (7 – 8 AM January)

<u>Summer</u>

Coincident peak reduction: 0.32 kW (4 – 5 PM August)

Maximum peak reduction: 0.55 kW (8 – 9 PM August)

Appendix 6 provides a summary of the integrated demand for the solar system (consisting of the solar pumps and water heater), and the electric water heater alone. Integrated demand is provided per hour for each month of the year.

Installation costs

The average cost of retrofitting a solar system into an existing home is $7,271. The lowest value noted was $4,000, and the highest value was $12,375. Appendix 8 summarizes information on system installation costs.

Impact of other variables

The impact of four variables was reviewed:

- Demographics (number of occupants in home)
- Seasonal variations (summer versus winter)
- Inlet water temperature (cold water delivered to the water heating system)
- Geographic location

Based upon the sample population, there was no significant variation in savings of a solar water heating system as a function of the number of occupants in the home. Water usage and the subsequent kWh savings from a solar thermal system was more a function of how the customers used water versus how many occupants were in the home.

Performance of the solar systems was significantly reduced during winter months, due to fewer hours of sunlight, and design criteria of the solar systems to prevent overheating in the summer months. Inlet water temperatures drop approximately 20 ° Fahrenheit from summer to winter, resulting in the water heating system requiring up to 50% more energy to produce the same amount of water at a given temperature. There were no significant variations in solar system performance in the three regions (Mountain, Piedmont and Coastal).

Appendix 10 provides more details on these items.

Customer surveys

Homeowners with solar systems were surveyed at the start of the data collection effort for the pilot program, and at the end of the program. Overall, every customer that responded was satisfied with their solar water heating systems, and would recommend a solar system to a friend or neighbor. Minor problems or issues were noted by those surveyed at the beginning, but there was no significant problem that impacted the majority of owners. After at least one year of operation, 25% of owners that responded reported problems with either leaks or pumps, but all problems have been resolved by the installer. Appendix 9 contains more information on the results of the surveys.

Other observations

Other observations are provided in Appendix 7 to this report.

Conclusions and recommendations

1. Retrofitting a solar water heating system to an existing residence in the Progress Energy service area can reduce the energy required to produce domestic hot water. The average annual savings were calculated at 63%, or 2,316 kWh.
2. Retrofitting a solar water heating system to an existing residence can reduce the integrated peak demand, as compared to a standard electric water heater. The coincident peak integrated demand savings are 0.44 kW during the winter months, and 0.32 kW during the summer months.
3. Actual energy and demand savings are a function of several variables, such as hot water usage, and the time of day that hot water is consumed. Therefore, the aforementioned energy and demand savings are averages, based upon the participants in the pilot program. Actual energy and demand savings vary widely for each individual home from the average values presented above.
4. Based on the data collected from homeowners and installers, the following recommendations should be considered for implementation if a permanent incentive program is established for solar domestic water heating systems to improve overall performance and customer satisfaction:
    a. *Warranty/maintenance*: A one year parts and labor (minimum) warranty should be provided with each solar system to minimize failures of the system. Extended warranties or service contracts may be considered to address possible system failures after the initial warranty period.
    b. *Storage tank location:* If practical, the storage tank(s) should be located in conditioned areas. Tanks located in unconditioned crawlspaces, exterior storage, and attics are subject to higher standby heat losses than a unit located inside the home.
    c. *Multiple storage tanks:* The overall effectiveness of a solar water heating system is directly impacted by the storage tank. In general, stratification (where hot water is naturally at the top of the tank, and cooler water is at the bottom) promotes a more efficient system. In crawl spaces that do not have adequate clearance for a standard tank, it is common to use multiple "lowboys", or 40 gallon tanks that are less than 3 feet in height. Although the total volume of two 40 gallon tanks is equal to a single 80 gallon tank, the stratification effect in a 3 foot tank is diminished as compared to a five or six foot tank. Therefore, use of multiple tanks should be avoided when practical.
    d. *Controls for backup heating element:* If the combination of the solar panels and the volume of the storage tank(s) is inadequate to provide all of the hot water consumed, then the heating element in the storage tank will activate to generate hot water. Activation of the heating element reduces both energy and demand savings of the system. Installers should evaluate each system prior to installation to see if a heating

element controller (or the function is integrated into the overall system controller) could minimize the operation of the heating element during peak system winter and summer hours, without impacting customer satisfaction.

e. *Alarm indication:* Every solar system controller has an alarm (typically a single red light) to alert the homeowner of a problem with the solar system. Unfortunately, the controller is mounted on the storage tank, which is not installed in a location where the homeowner can see the alarm light. Alternative locations for alarm lights, or the use of an audible alarm (buzzer) would be recommended so that the customer can address problems with the system in a timely manner.
f. *Installer qualifications:* To mitigate potential problems with selection of components, sizing of the storage tank(s) and panels, and maintenance issues, the installing contractors should be certified by the North American Board of Certified Energy Practitioners (NABCEP). Installing contractors should adhere to the requirements and recommendations of the NABCEP regarding the design and installation of solar domestic hot water systems.

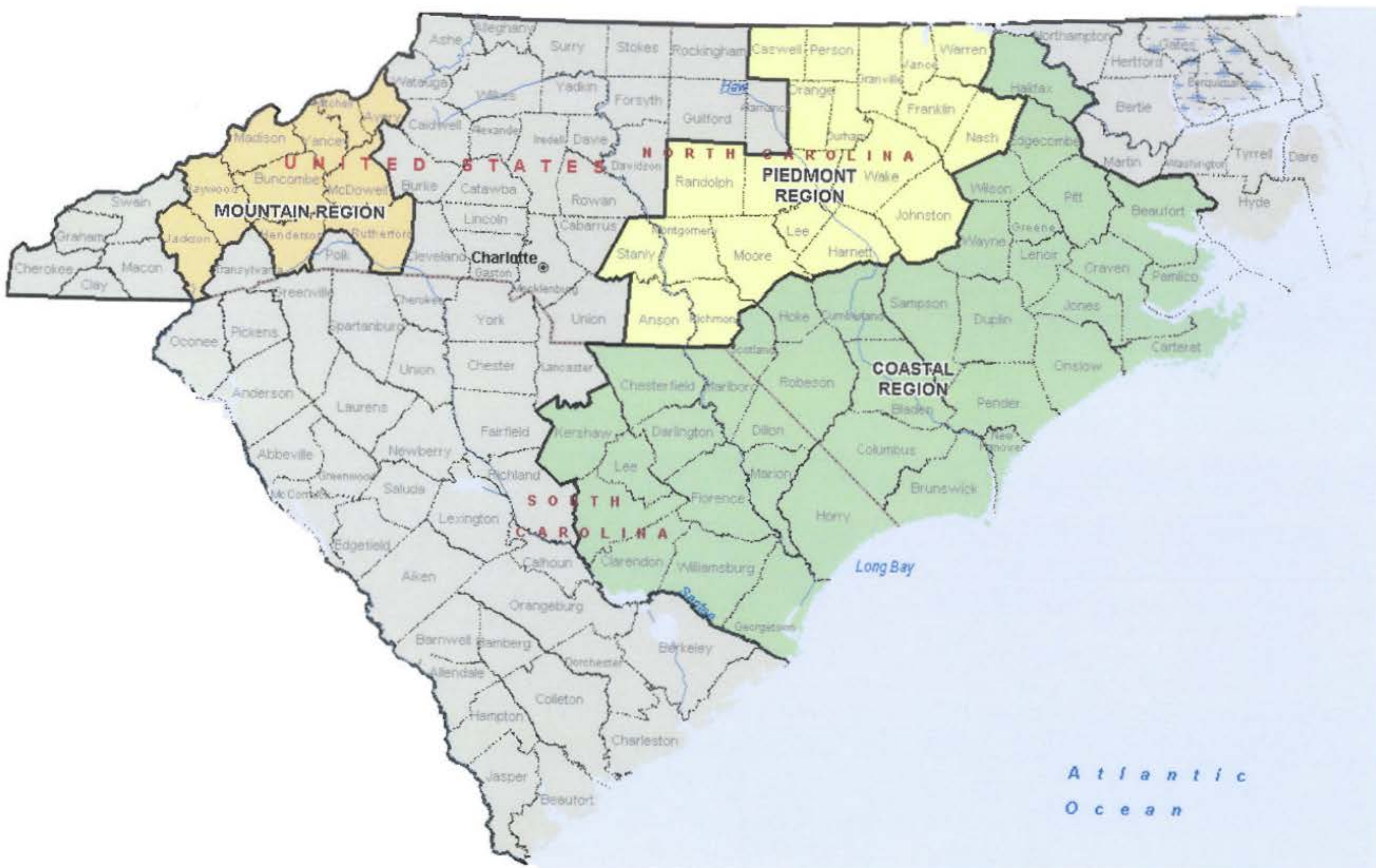
Appendix 1: Map of instrumented customers

The map provided in this appendix shows the three geographical regions (Mountain, Piedmont, and Coastal) of the 60 households in North and South Carolina that were monitored for the performance of their solar water heating systems.

PROGRESS ENERGY CAROLINAS

SOLAR WATER HEATING PROGRAM

GEOGRAPHICAL REGIONS FOR INSTRUMENTED CUSTOMERS



Appendix 2: Instrumented customer data summary

A summary of data for each of the instrumented customers is provided in this appendix. Refer to the notes below regarding the information:

Notes

1. Occupants – Lists the total number of occupants in the home full time, the number of occupants below the age of 18, and the number of occupants that are at home during the day, Monday – Friday.
2. System type – System type is either drainback ("DRAINBACK") or pressurized glycol ("GLYCOL").
3. Panel type – The solar panels are either flat ("FLAT"), or evacuated tube ("EVAC").
4. Space heat – Notes if the solar system was used to heat the home in addition to producing hot water.
5. Electric water heater – The storage tank capacity for the solar system is listed in nominal gallons. If an additional storage tank was provided, its capacity is under 'extra tank gal'. The temperature setpoint of the storage tank when the solar system is in operation is given under 'system setpoint', while the temperature setpoint of the storage tank with the solar system not in operation is given under 'tank setpoint'. The location of the heat exchanger that separates the solar panels from the hot water for consumption is given under 'HX int/ext', where 'int' refers to a heat exchanger internal to the storage tank, and 'ext' refers to a heat exchanger located outside the storage tank.

SOLAR WATER HEATING PILOT PROGRAM
CUSTOMER DATA SUMMARY

	OCCUPANTS			SOLAR					PUMPS			ELECTRIC WATER HEATER					
CUST. #	TOTAL OCCUP.	< 18 OCCUP.	M - F OCCUP.	SYSTEM TYPE	PANEL TYPE	# PANELS	PANEL AREA	SPACE HEAT?	# PUMPS	PUMP AMPS	PUMP KW	TANK GAL.	EXTRA TANK GAL	TANK LOCATION	SYSTEM SETPOINT	TANK SETPOINT	HX INT/EXT?
1	3	0	2	DRAINBACK	FLAT	2	31.8	NO	2	0.49	0.08	80	0	ATTIC	160	90	EXT
2	*	*	*	GLYCOL	FLAT	3	25.0	NO	1	0.75	0.06	120	0	BASEMENT	160	90	INT
3	2	0	1	DRAINBACK	FLAT	2	31.8	NO	2	0.49	0.08	120	0	BASEMENT	160	90	EXT
4	3	1	1	DRAINBACK	FLAT	2	31.8	NO	2	0.49	0.08	50	80	CRAWLSPACE	160	90	EXT
5	3	1	1	DRAINBACK	EVAC	1	44.8	NO	2	0.49	0.08	80	0	BASEMENT	160	90	EXT
6	3	1	2	GLYCOL	FLAT	2	23.1	NO	1	0.75	0.06	80	0	BASEMENT	150	90	INT
7	4	2	4	DRAINBACK	FLAT	2	31.8	NO	2	0.49	0.08	80	0	BASEMENT	160	90	EXT
8	*	*	*	GLYCOL	FLAT	2	23.1	NO	1	0.75	0.06	40	80	CRAWLSPACE	150	90	INT
9	6	4	1	GLYCOL	FLAT	2	25.0	NO	1	0.75	0.06	80	0	GARAGE	160	90	INT
10	4	2	1	DRAINBACK	FLAT	2	31.8	NO	2	0.49	0.08	40	120	CRAWLSPACE	160	90	EXT
11	3	0	2	GLYCOL	FLAT	2	23.1	NO	1	0.75	0.06	40	80	CRAWLSPACE	150	90	INT
12	1	0	0	GLYCOL	FLAT	2	23.1	NO	1	0.75	0.06	80	0	GARAGE	150	90	INT
13	2	0	0	GLYCOL	FLAT	2	23.1	NO	1	0.75	0.06	80	0	GARAGE	150	90	INT
14	3	1	2	GLYCOL	FLAT	2	25.0	NO	1	0.75	0.06	80	0	CRAWLSPACE	160	90	INT
15	4	2	2	GLYCOL	FLAT	2	25.0	NO	1	1.00	0.08	80	0	CRAWLSPACE	160	90	INT
16	1	0	0	DRAINBACK	FLAT	2	31.8	NO	2	0.49	0.08	80	0	INSIDE	160	90	EXT
17	2	0	2	DRAINBACK	EVAC	1	37.2	NO	2	0.49	0.08	50	80	CRAWLSPACE	160	90	EXT
18	3	0	1	GLYCOL	FLAT	2	23.1	NO	2	0.49	0.08	80	0	BASEMENT	150	90	INT
19	3	1	0	GLYCOL	FLAT	2	31.8	NO	1	0.75	0.06	80	0	GARAGE	175	90	INT
20	4	2	3.5	DRAINBACK	FLAT	2	31.8	NO	2	0.49	0.08	120	0	GARAGE	160	90	EXT
21	2	0	2	GLYCOL	FLAT	2	*	NO	0	0	0.00	80	0	ATTIC	160	90	INT
22	6	4	1	DRAINBACK	FLAT	2	26.3	NO	2	0.49	0.08	80	0	GARAGE	160	90	EXT
23	*	*	*	DRAINBACK	FLAT	2	31.5	NO	2	0.49	0.08	80	0	GARAGE	160	90	EXT
24	3	1	2	DRAINBACK	FLAT	2	31.5	NO	2	0.49	0.08	80	0	ATTIC	160	90	EXT
25	3	1	0	GLYCOL	FLAT	1	43.1	NO	2	0.49	0.08	80	0	GARAGE	170	90	INT
26	2	0	0	GYCOL	FLAT	2	26.3	NO	1	0.35	0.03	80	0	INSIDE	165	90	INT
27	2	0	2	DRAINBACK	FLAT	2	26.3	NO	2	0.49	0.08	80	0	INSIDE	160	90	EXT
28	2	0	2	GLYCOL	EVAC	1	31.9	NO	1	0.35	0.03	80	0	INSIDE	150	90	INT
29	3	1	2	GLYCOL	FLAT	2	26.3	NO	2	0.49	0.08	80	0	GARAGE	160	90	INT
30	5	3	1	DRAINBACK	FLAT	2	39.3	NO	2	0.49	0.08	120	0	GARAGE	170	90	EXT
31	4	2	2	GLYCOL	FLAT	2	31.5	NO	1	1.5	0.12	80	0	GARAGE	165	90	INT
32	2	0	2	GLYCOL	FLAT	1	31.5	NO	2	0.49	0.08	80	0	GARAGE	170	90	INT
33	4	2	6	DRAINBACK	FLAT	2	31.5	NO	2	0.49	0.08	40	80	GARAGE	140	90	EXT
34	3	0	1	GLYCOL	FLAT	2	39.7	NO	2	0.49	0.08	80	0	INSIDE	160	90	INT
35	2	0	1	GLYCOL	FLAT	2	25.0	NO	1	0.75	0.06	80	0	INSIDE	160	90	INT
36	2	0	2	DRAINBACK	FLAT	2	39.7	NO	1	0.75	0.06	119	0	BASEMENT	160	90	EXT
37	2	0	2	GLYCOL	FLAT	3	25.0	NO	1	0.75	0.06	120	0	GARAGE	160	90	INT
38	2	0	2	DRAINBACK	FLAT	2	31.5	NO	2	0.49	0.08	80	0	GARAGE	160	90	EXT
39	4	2	0	DRAINBACK	FLAT	1	31.5	NO	2	0.49	0.08	80	0	GARAGE	170	90	EXT
40	3	1	3	DRAINBACK	FLAT	2	31.5	NO	2	0.49	0.08	80	0	GARAGE	160	90	EXT
41	*	*	*	GLYCOL	FLAT	2	39.7	NO	1	0.75	0.06	*	*	BASEMENT	170	90	INT
42	2	0	1	GLYCOL	FLAT	2	31.5	NO	1	0.75	0.06	80	0	GARAGE	170	90	INT
43	2	0	2	GLYCOL	FLAT	2	39.7	YES	2	0.75	0.12	76	0	CRAWLSPACE	170	90	INT
44	1	0	1	GLYCOL	FLAT	2	31.5	NO	2	0.75	0.12	76	0	CRAWLSPACE	170	90	INT
45	2	0	2	GLYCOL	FLAT	1	39.7	NO	1	0.75	0.06	65	0	BASEMENT	170	90	INT
46	2	0	1	GLYCOL	FLAT	2	40.8	NO	1	0.75	0.06	80	0	CRAWLSPACE	180	90	INT
47	*	*	*	DRAINBACK	FLAT	2	31.5	NO	2	0.49	0.08	50	50	GARAGE	140	90	EXT
48	2	0	0	GLYCOL	FLAT	3	39.7	NO	1	0.75	0.06	50	0	GARAGE	180	90	INT
49	1	0	1	GLYCOL	FLAT	2	39.7	NO	2	0.49	0.08	50	80	BASEMENT	180	90	INT
50	3	1	2	GLYCOL	FLAT	2	39.7	NO	1	0.75	0.06	50	0	BASEMENT	180	90	INT
51	4.5	0	2	GLYCOL	FLAT	2	39.7	NO	1	0.75	0.06	50	0	INSIDE	180	90	INT

SOLAR WATER HEATING PILOT PROGRAM
CUSTOMER DATA SUMMARY

	OCCUPANTS			SOLAR					PUMPS			ELECTRIC WATER HEATER					
CUST. #	TOTAL OCCUP.	< 18 OCCUP.	M - F OCCUP.	SYSTEM TYPE	PANEL TYPE	# PANELS	PANEL AREA	SPACE HEAT?	# PUMPS	PUMP AMPS	PUMP KW	TANK GAL.	EXTRA TANK GAL	TANK LOCATION	SYSTEM SETPOINT	TANK SETPOINT	HX INT/EXT?
52	2	2	1	GLYCOL	FLAT	5	39.7	YES	1	0.75	0.06	119	0	BASEMENT	180	90	INT
53	*	*	*	GLYCOL	FLAT	1	39.7	NO	1	0.75	0.06	110	0	BASEMENT	170	90	INT
54	2	0	0	GLYCOL	FLAT	1	39.7	NO	1	0.75	0.06	80	0	CRAWLSPACE	180	90	INT
55	2	0	1	GLYCOL	FLAT	2	39.7	NO	1	0.75	0.06	80	0	BASEMENT	180	90	INT
56	2	0	1	GLYCOL	FLAT	1	39.7	NO	1	0.75	0.06	80	0	GARAGE	170	90	INT
57	2	2	1	GLYCOL	FLAT	2	39.7	NO	1	0.75	0.06	50	0	BASEMENT	180	90	INT
58	2	0	1	GLYCOL	FLAT	1	39.7	NO	2	0	0.00	100	0	CRAWLSPACE	165	90	INT
59	*	*	*	GLYCOL	FLAT	1	39.7	NO	1	0.75	0.06	65	0	GARAGE	180	90	INT
60	1	0	0	GLYCOL	FLAT	2	39.7	NO	1	0.75	0.06	80	0	INSIDE	180	90	INT

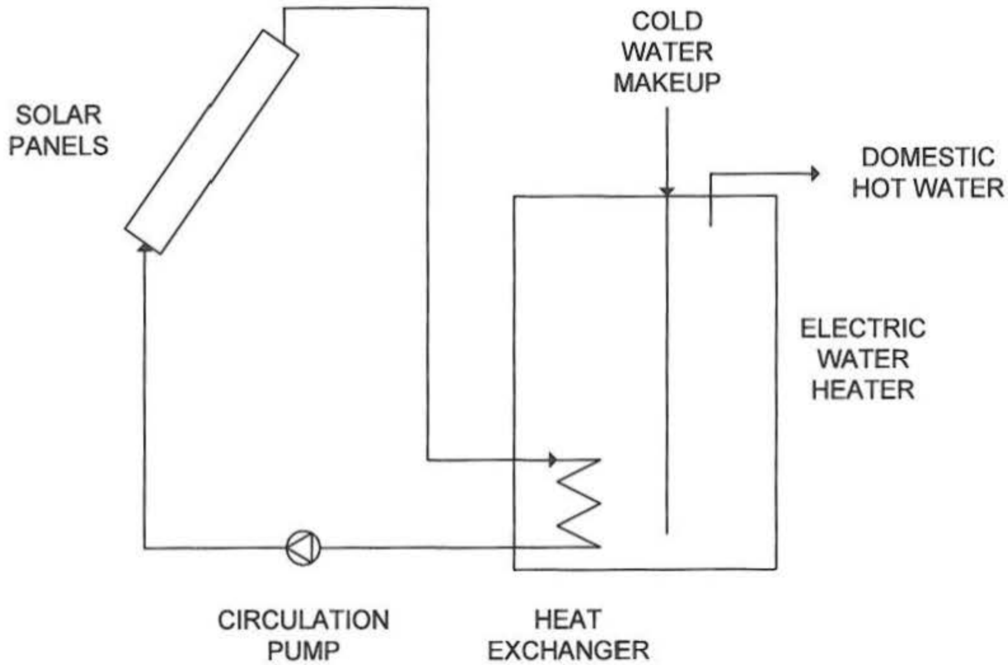
Appendix 3: Solar system schematics

Basic schematics of major components for the two types of solar water heating systems, pressurized glycol and drainback, are provided in this appendix.

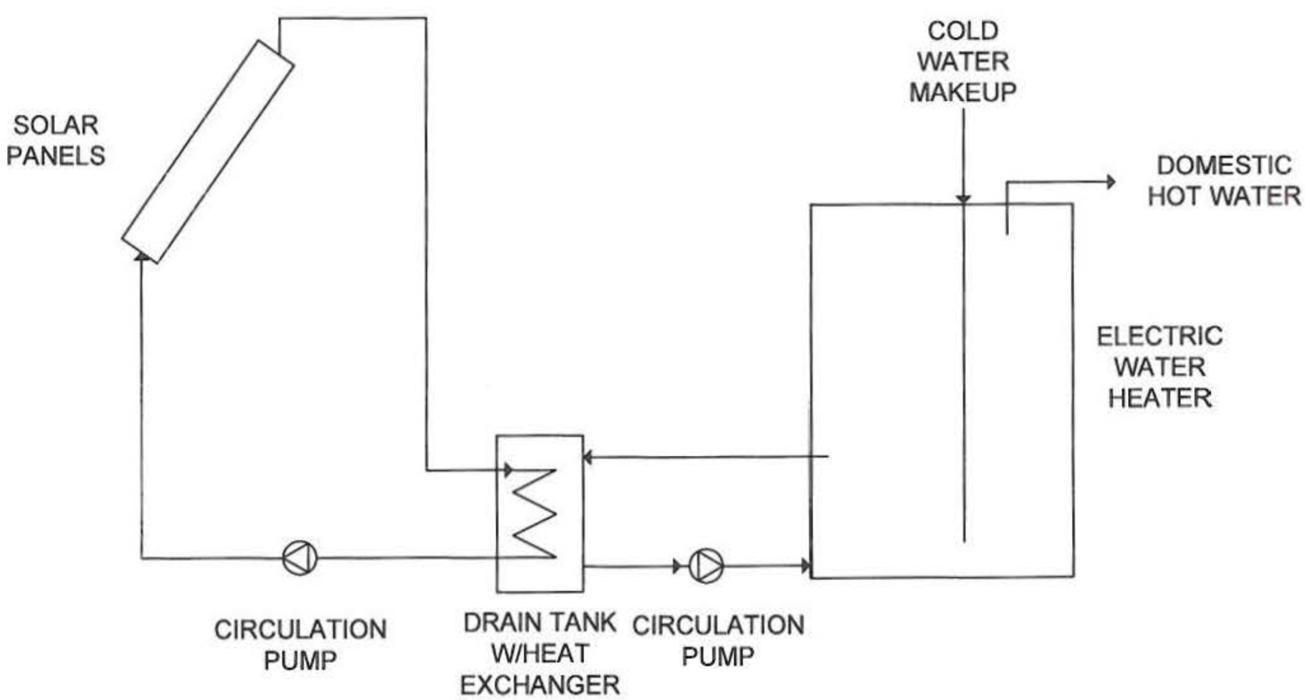
The pressurized glycol system pumps a propylene glycol solution through the solar panels, and then through a heat exchanger located within the storage tank. The heat exchanger is required to prevent mixing of the glycol solution with the domestic hot water.

The drain back system also pumps a glycol solution through the panels to a heat exchanger. However, the heat exchanger is locate in a separate tank, and not the storage tank. In the event the system either potentially freezes or overheats, the system will automatically drain the glycol solution into the drainback tank.

SIMPLIFIED PRESSURIZED GYLCOL SCHEMATIC



SIMPLIFIED DRAINBACK SCHEMATIC



Appendix 4: Data logger installation photos

Event data logger on electric water heater cable.

Event data logger on solar circulation pump housing.

Temperature data logger for inlet water temperature to electric water heater.

Appendix 5: Summary of energy usage

A summary of the average hourly energy consumption (in kWh) for each hour of each month for the solar systems (with electric water heater as backup), and for electric water heaters only (no solar input), along with the savings (electric water heater only – solar) is provided in tabular form on the next page. As noted in Appendix 7 of this report, when the solar systems were disabled, hot water was generated by the single heating element in the storage tank to maintain a nominal 90° Fahrenheit setpoint. To generate the energy usage (and demand impact) of a standalone electric water heater with a nominal 120° Fahrenheit setpoint, the kWh and kW values measured with a 90° Fahrenheit setpoint were interpolated to reflect the energy and integrated demand of a 120° Fahrenheit setpoint unit.

SUMMARY OF ANNUAL AVERAGE ENERGY USAGE / INTEGRATED DEMAND IMPACTFOR SOLAR SYSTEM VERSUS ELECTRIC WATER HEATER

(NOTE: the values in the table below represent the energy [in kWh] associated with the solar system and the electric water heater, as well as the integrated demand impact [in kW]

TOTAL solar and hw heater **energy, kWh, and integrated demand, kW**

	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM	Total kWh
jan	0.21	0.15	0.17	0.13	0.11	0.13	0.16	0.33	0.47	0.48	0.51	0.52	0.48	0.41	0.37	0.27	0.25	0.35	0.31	0.33	0.37	0.36	0.30	0.24	229
feb	0.17	0.14	0.14	0.13	0.16	0.19	0.22	0.40	0.40	0.42	0.34	0.36	0.36	0.26	0.25	0.17	0.18	0.25	0.33	0.33	0.30	0.32	0.22	0.22	175
mar	0.10	0.08	0.09	0.12	0.13	0.21	0.36	0.35	0.36	0.33	0.31	0.25	0.21	0.17	0.13	0.13	0.13	0.16	0.17	0.18	0.22	0.17	0.15	0.12	139
apl	0.07	0.05	0.06	0.08	0.10	0.20	0.31	0.29	0.30	0.30	0.26	0.18	0.15	0.12	0.10	0.09	0.08	0.09	0.11	0.12	0.12	0.10	0.09	0.07	104
may	0.05	0.05	0.06	0.06	0.11	0.21	0.27	0.23	0.23	0.23	0.16	0.14	0.11	0.08	0.08	0.07	0.07	0.08	0.09	0.09	0.08	0.08	0.07	0.06	86
jun	0.01	0.01	0.02	0.02	0.03	0.06	0.08	0.16	0.16	0.16	0.13	0.12	0.09	0.08	0.06	0.06	0.04	0.05	0.05	0.03	0.01	0.01	0.02	0.01	44
jul	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.07	0.09	0.11	0.09	0.08	0.08	0.06	0.05	0.04	0.03	0.03	0.04	0.03	0.01	0.01	0.01	0.01	27
aug	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.06	0.08	0.10	0.08	0.07	0.07	0.05	0.04	0.04	0.03	0.03	0.04	0.03	0.01	0.01	0.01	0.01	25
sep	0.04	0.04	0.03	0.04	0.04	0.05	0.09	0.14	0.10	0.14	0.17	0.14	0.11	0.08	0.07	0.06	0.05	0.07	0.08	0.09	0.07	0.06	0.04	0.05	55
oct	0.11	0.06	0.05	0.07	0.06	0.08	0.24	0.43	0.25	0.27	0.30	0.25	0.18	0.18	0.13	0.13	0.12	0.12	0.18	0.31	0.25	0.16	0.13	0.12	130
nov	0.13	0.11	0.09	0.06	0.08	0.10	0.15	0.31	0.33	0.36	0.41	0.36	0.32	0.25	0.19	0.17	0.17	0.15	0.19	0.17	0.18	0.20	0.18	0.17	145
dec	0.19	0.15	0.14	0.12	0.10	0.11	0.17	0.32	0.42	0.41	0.51	0.49	0.41	0.36	0.34	0.25	0.25	0.29	0.24	0.30	0.33	0.34	0.29	0.22	209

Annual solar pump & backup heater energy, kWh 1368

Electric water heater only **energy, kWh**, and integrated **demand, kW**

	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM	Total kWh
jan	0.28	0.23	0.19	0.22	0.24	0.29	0.75	0.96	0.91	0.83	0.68	0.57	0.50	0.45	0.44	0.38	0.45	0.57	0.67	0.75	0.67	0.53	0.52	0.41	387
feb	0.25	0.21	0.17	0.20	0.21	0.26	0.67	0.86	0.81	0.74	0.61	0.51	0.45	0.40	0.39	0.34	0.40	0.51	0.60	0.67	0.60	0.47	0.46	0.36	312
mar	0.26	0.22	0.18	0.21	0.22	0.27	0.71	0.90	0.85	0.78	0.64	0.54	0.47	0.42	0.41	0.35	0.42	0.54	0.63	0.71	0.63	0.50	0.49	0.38	352
apl	0.24	0.20	0.17	0.19	0.20	0.25	0.65	0.83	0.79	0.72	0.59	0.50	0.44	0.39	0.38	0.33	0.39	0.50	0.58	0.65	0.58	0.46	0.45	0.35	325
may	0.25	0.21	0.17	0.20	0.21	0.26	0.68	0.87	0.82	0.75	0.62	0.52	0.46	0.41	0.40	0.34	0.41	0.52	0.61	0.68	0.61	0.48	0.47	0.37	351
jun	0.14	0.15	0.14	0.16	0.21	0.19	0.37	0.59	0.51	0.47	0.45	0.34	0.31	0.30	0.31	0.30	0.37	0.41	0.52	0.58	0.60	0.49	0.38	0.31	258
jul	0.12	0.13	0.13	0.14	0.18	0.17	0.33	0.52	0.45	0.41	0.40	0.30	0.28	0.27	0.27	0.26	0.33	0.36	0.45	0.51	0.53	0.43	0.34	0.30	236
aug	0.13	0.14	0.13	0.15	0.19	0.18	0.34	0.55	0.47	0.43	0.42	0.32	0.29	0.28	0.29	0.28	0.34	0.38	0.48	0.54	0.56	0.45	0.35	0.29	248
sep	0.14	0.15	0.15	0.16	0.21	0.20	0.38	0.61	0.52	0.48	0.47	0.35	0.32	0.31	0.32	0.31	0.38	0.43	0.53	0.60	0.62	0.50	0.39	0.32	266
oct	0.15	0.16	0.15	0.17	0.22	0.20	0.39	0.63	0.54	0.50	0.48	0.36	0.33	0.32	0.33	0.32	0.39	0.44	0.55	0.62	0.64	0.52	0.41	0.33	283
nov	0.17	0.18	0.18	0.19	0.26	0.23	0.45	0.73	0.63	0.57	0.56	0.42	0.39	0.37	0.38	0.37	0.46	0.51	0.63	0.72	0.74	0.60	0.47	0.38	317
dec	0.18	0.19	0.19	0.21	0.27	0.25	0.49	0.78	0.67	0.61	0.59	0.45	0.41	0.40	0.41	0.39	0.49	0.54	0.68	0.76	0.78	0.64	0.50	0.40	350

Annual electric water heater only energy, kWh **3684**

SAVINGS: (Electric water heater only) - (Solar pump + HW heater backup) energy [kWh] and integrated demand [kW]

	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM	Total kWh
jan	0.06	0.08	0.02	0.10	0.13	0.16	0.59	0.63	0.44	0.35	0.17	0.06	0.03	0.04	0.07	0.11	0.20	0.22	0.36	0.42	0.31	0.17	0.22	0.17	158
feb	0.08	0.07	0.03	0.07	0.05	0.07	0.45	0.46	0.41	0.32	0.26	0.16	0.08	0.14	0.14	0.17	0.22	0.26	0.27	0.34	0.30	0.16	0.24	0.14	137
mar	0.16	0.14	0.09	0.09	0.09	0.06	0.35	0.55	0.49	0.44	0.33	0.29	0.26	0.25	0.28	0.22	0.29	0.38	0.45	0.52	0.42	0.33	0.33	0.26	213
apl	0.17	0.15	0.10	0.11	0.10	0.05	0.35	0.54	0.49	0.42	0.33	0.32	0.28	0.27	0.28	0.24	0.31	0.40	0.47	0.53	0.47	0.36	0.35	0.28	221
may	0.20	0.16	0.12	0.15	0.10	0.05	0.41	0.64	0.60	0.52	0.45	0.38	0.35	0.33	0.32	0.27	0.34	0.44	0.51	0.59	0.53	0.40	0.40	0.31	266
jun	0.13	0.13	0.13	0.14	0.18	0.13	0.29	0.43	0.34	0.31	0.33	0.23	0.22	0.22	0.25	0.24	0.33	0.37	0.47	0.55	0.58	0.47	0.36	0.30	214
jul	0.12	0.13	0.12	0.13	0.18	0.16	0.31	0.46	0.35	0.30	0.31	0.22	0.20	0.21	0.23	0.22	0.30	0.33	0.42	0.49	0.52	0.42	0.33	0.29	209
aug	0.12	0.13	0.13	0.14	0.19	0.17	0.33	0.49	0.39	0.33	0.34	0.25	0.23	0.23	0.24	0.24	0.32	0.35	0.44	0.51	0.55	0.45	0.35	0.28	223
sep	0.10	0.12	0.12	0.13	0.17	0.15	0.29	0.47	0.42	0.34	0.30	0.21	0.22	0.23	0.25	0.25	0.33	0.36	0.46	0.51	0.55	0.44	0.35	0.27	210
oct	0.04	0.09	0.11	0.10	0.17	0.12	0.16	0.20	0.29	0.22	0.18	0.11	0.15	0.14	0.20	0.19	0.27	0.32	0.36	0.30	0.38	0.36	0.28	0.20	153
nov	0.04	0.07	0.08	0.13	0.17	0.13	0.31	0.42	0.30	0.22	0.15	0.06	0.06	0.12	0.19	0.20	0.28	0.36	0.45	0.55	0.55	0.40	0.29	0.21	172
dec	-0.01	0.04	0.05	0.08	0.17	0.14	0.32	0.46	0.25	0.21	0.08	-0.04	0.00	0.04	0.07	0.14	0.23	0.25	0.43	0.47	0.46	0.30	0.21	0.18	140

Annual energy, kWh, saved **2316**

Percentage savings **63%**

Appendix 6: Summary of integrated demand impact

A summary of the average hourly integrated demand (in kW) for each hour of each month for the solar systems (with electric water heater as backup), and for electric water heaters only (no solar input), along with the savings (electric water heater only – solar) is provided in tabular form in Appendix 5. Graphs of the Progress Energy peak demand curves for winter and summer are provided, along with the demand curves for the solar system and electric water heater only for one year. The water heating demand curves have been adjusted (normalized) to show the relative contribution to PEC's peak system demand.

The coincident and maximum demand reductions for winter and summer are provided below:

<u>Winter</u>

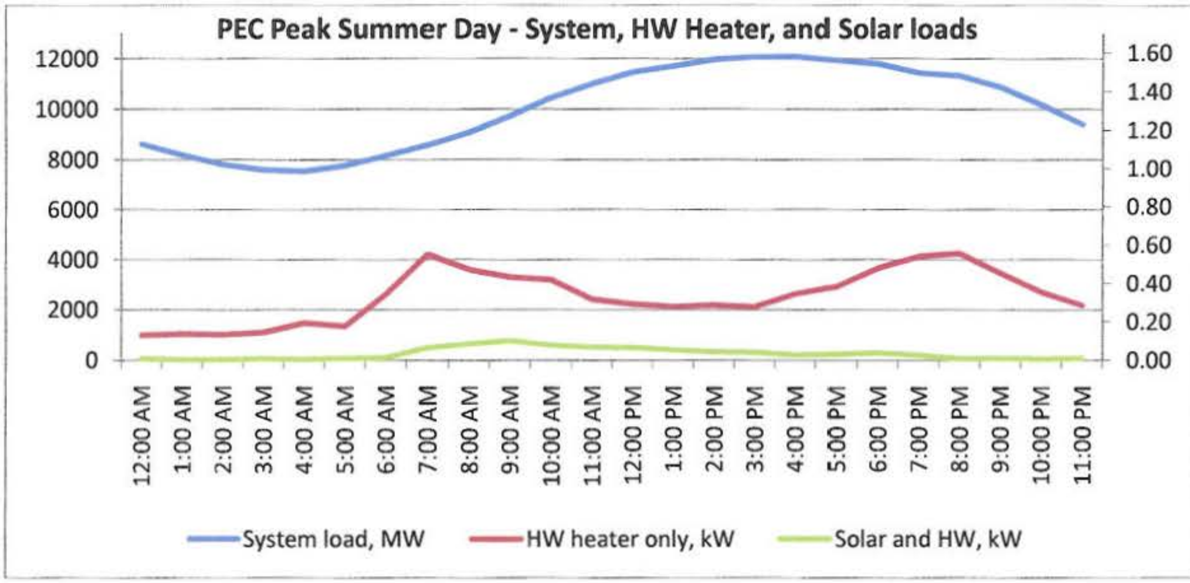
Coincident peak reduction: 0.44 kW (8 – 9 AM January)

Maximum peak reduction: 0.63 kW (7 – 8 AM January)

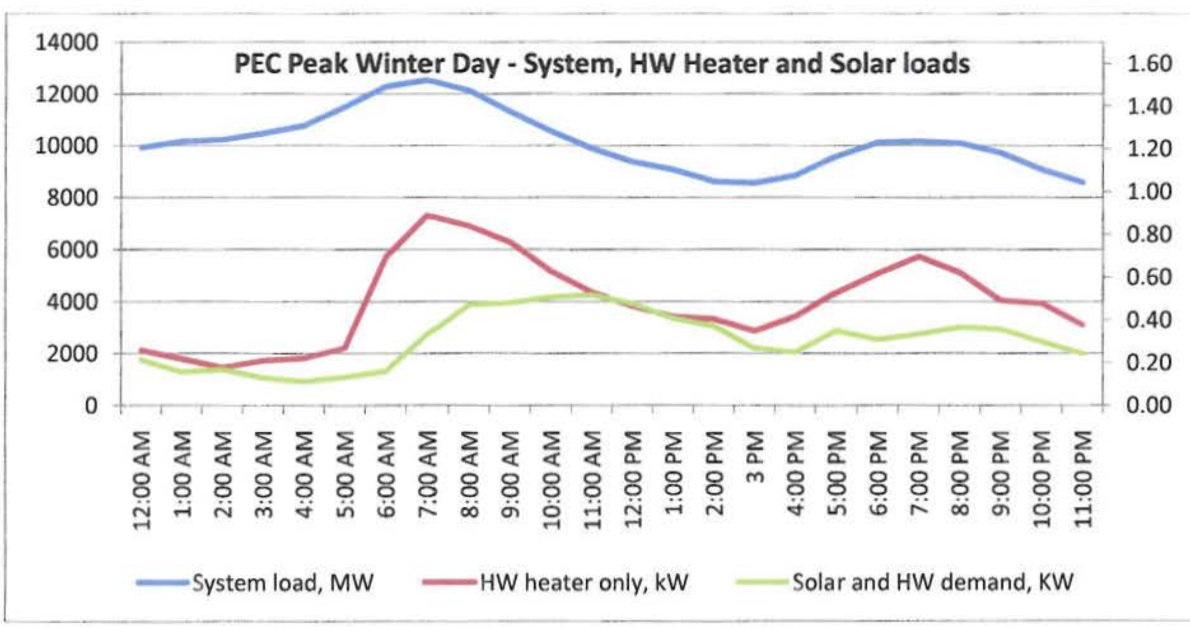
<u>Summer</u>

Coincident peak reduction: 0.32 kW (4 – 5 PM August)

Maximum peak reduction: 0.55 kW (8 – 9 PM August)



Note: The values for the System load are in MW, and are shown on the left axis. The values for the hot water heater only and solar and hot water heater backup are in kW, and are shown on the right axis.



Appendix 7: General program implementation observations

Implementation issues

Overall, customers were co-operative and helpful in the execution of the data logging installation, data collection, and providing information about their households and systems. This is also true of the installers as well. Any implementation issues encountered to date were considered to be minor in nature, and are summarized below:

1. A simplifying assumption of the program is that the hot water consumption would be constant on a weekly basis during the data collection effort. Some households had increases or decreases in occupants during either the period when data was collected with the solar system on, versus when data was collected when the solar system was off (electric water heater only). A change in the number of occupants impacts the hot water consumption, which in turn impacts the savings calculations. Where ever possible, the customers were surveyed to determine if the occupancy changed during the data collection periods, and this was noted on the summary calculations.

2. Approximately 25% of installations had equipment or controller failures or problems during the year, leading to incomplete or inaccurate data. These items were brought to the attention of the contractors and customers.

3. A few of the data loggers failed to operate properly, leading to lost data. These data loggers were either replaced or adjusted. Some of the dataloggers were accidently destroyed by the solar contractors by exposing the dataloggers to water when the systems were disabled.

4. Since the data logging efforts started during the summer months, some of the occupants went on vacation during the data logging efforts; however their data collection time was extended to meet minimum logging times as needed.

5. Operation of the solar system pumps was recorded via data loggers for a year (or more) for each customer. Measurements of just the hot water heating element were taken by disabling the solar system for a minimum of two weeks during the summer/fall, and again during the winter season. The electric-only heating energy and integrated demand values were then interpolated to recognize each month of the year based on the "Annual pattern of whole sample volumetric consumption", as presented in Appendix 11, Reference 12, Figure 6.19.

6. The majority of the pressurized glycol systems were not equipped with a separate means of rejecting heat, and they were deactivated by partially draining the system to remove fluid from the collectors on the roof. In some cases, the Program personnel drained the systems, and in other cases, the original contractor was paid to drain the systems. The original contractor was paid to refill and restart the impacted systems. Interfacing with the contractor did cause a delay in completion of the data collection effort for some homeowners.

7. The typical storage tank for solar systems is provided with a single heating element, located in the upper third of the tank. The element provides hot water in the event that the tank temperature drops below setpoint, and when the solar panels cannot heat the water. The setpoint for the backup heating element

is typically 90° Fahrenheit. A stand alone electric water heater will typically have a setpoint of 120° Fahrenheit, and have two elements, one in the upper third of the tank, and the other in the lower third of the tank. The lower element is normally the only element that is active. By using the lower element as the source of heating, the stand alone electric water heater contains more water at setpoint, and at a higher temperature, than a backup tank for a solar system. Some of the program participants noted that when the solar system was not active (either due to weather or a problem) that the hot water from the backup tank was "cooler" than normal. Although operation of the backup tank in this manner results in lower energy consumption, it may be desirable to provide a backup tank with two heating elements and appropriate controls to insure that the homeowners have sufficient hot water at a comfortable temperature when the solar system is unavailable for extended periods of time.

Appendix 8: Solar system installation costs

Participants in the pilot study procured solar water heating systems from a program approved installer. The cost of the retrofit included the following basic costs:

- Removal of existing electric water heater
- Installation of new storage tank
- Installation of solar panels on roof
- Routing of new pipes, connection to existing piping
- Installation of new pump(s), system controller, and drainback tank (drainback systems only)

The typical installation included two solar panels, and a nominal 80 gallon storage tank. A few systems had 1 or 3 panels, and a few systems had greater (or less) than 80 gallons storage, but the vast majority of the systems consisted of two solar panels and an 80 gallon storage tank.

The following system installation cost values were derived from the program participants' responses:

Average system installation cost:	\$7,271
Maximum system installation cost:	\$12,375
Minimum system installation cost:	\$4,000

Appendix 9: Homeowner survey results

The program participants with monitored solar systems were provided with a survey at the beginning of the data collection effort in 2010, and again at the end of the data collection effort in 2011. The first survey covered hot water usage and details about the solar system, as well as overall customer satisfaction with the system, and any problems noted with the system or its installation. The second survey was conducted approximately a year later, and focused exclusively on feedback concerning satisfaction, issues, or problems after the system had been running for at least one year.

The results of the surveys are summarized below. The percentage value associated with a response is relative to the number of surveys completed and returned. Every homeowner that responded stated that they were satisfied with the purchase of a solar water heating system, and would recommend a solar system to friends and neighbors. Issues with equipment, performance or other items occurred with some homeowners, but there was no one significant issue that was common to the majority of the installations.

Initial survey results

Query	**% Positive Response**
Satisfied with purchase of solar system, and would recommend to friend or neighbor	100%
Issues (equipment, operation, installation, etc.)	
Pumps	7%
Leaks	3%
Mixing valve	1%
Low water temperature and/or insufficient hot water	8%
Would only purchase if tax credits and incentives provided	3%
No perceived savings on monthly electric bill	3%
Problem with installer	1%
System stopped functioning, and homeowner did not know	3%

Final survey results

Query	**% Positive Response**
System has met homeowner expectations for providing hot water	100%
System has met homeowner expectations for reducing power bill*	67%*
Recommend solar water heating system to a friend or neighbor	100%
Any problems with system during or after warranty period**	25%**

*All non-positive responses were for homeowners that could not confirm the amount of savings; there were no negative responses or responses indicating that the system did not reduce the power bill.

**Problems after at least one year of operation consist of leaks and pump problems.

Appendix 10: Impact on savings due to demographics, seasonal variations, inlet water temperature and geographic location

Sixty program participants were chosen to have monitoring equipment temporarily installed to measure the performance of their solar water heating system, and to assess their hot water usage. The monitored households were chosen on the basis of number of occupants and geographic location within the Progress Energy Carolinas service area in North and South Carolina. This section summaries the impact on the relative savings of a solar water heating system (versus an electric water heater) as a function of:

- Demographics (number of occupants)
- Seasonal variations (summer versus winter)
- Inlet water temperature (cold water delivered into the water heating system)
- Geographic location

Conclusions

1. There were not significant variations in savings as a function of the number of household occupants.
2. The majority of the solar systems produced over 85% of the hot water needs during the summer months. During the winter months, the average percentage of hot water produced by the solar systems drops to 45%.
3. The inlet water temperature varied an average 20 degF from mid-winter to mid-summer. The lower inlet water temperatures in the winter reduce the effectiveness of the solar water heating systems, and increase the amount of hot water generated by the electric water heater (or heating element in the storage tank).
4. There was not a significant variation in energy and demand savings as a function of geographic location.

Demographics

The relative percentage savings for a solar system (for the summer/fall of 2010) as a function of the number of occupants is provided in the table below.

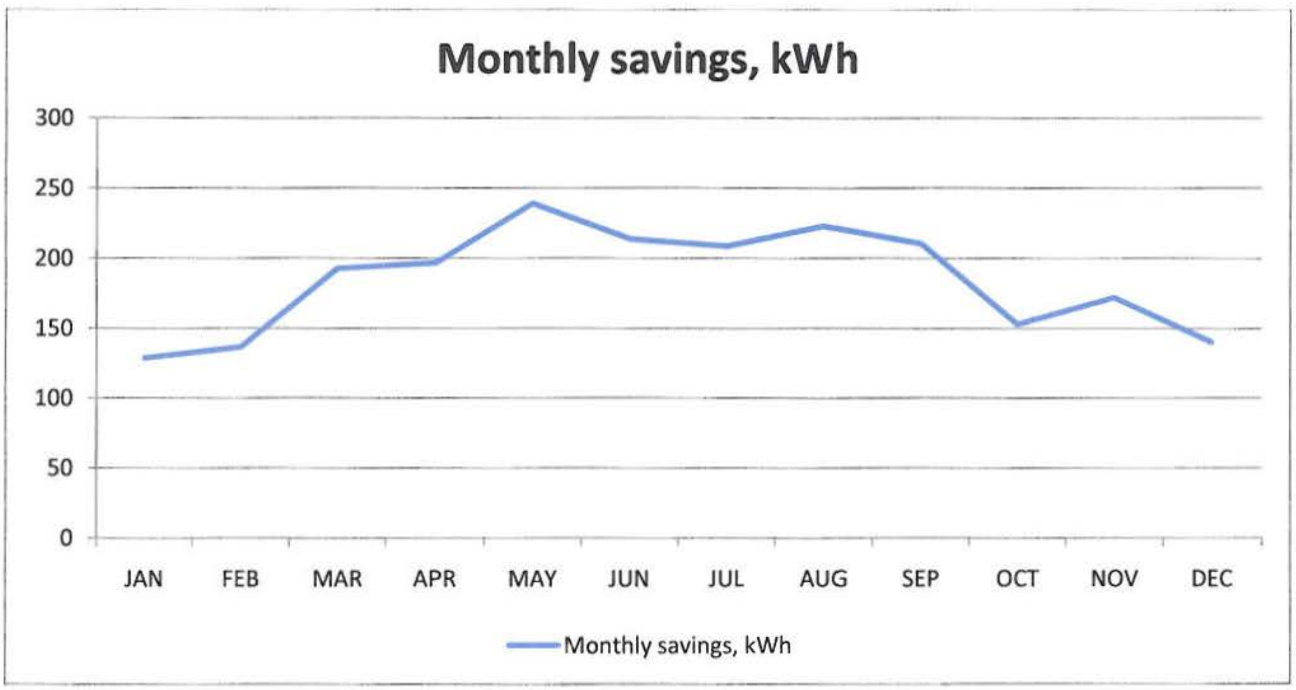
Number of Occupants	Total households	Average % solar savings
1	6	89%
2	27	91%
3	16	84%
4	8	83%
5	1	81%
6	2	85%

Although the average % solar savings is lower as the number of occupants increases, the difference between the highest and lowest savings values is less than 11%. This variation is not considered to be statistically significant, as the number of households for 4 or more occupants is not as large as for the 2 or 3 occupant households. Industry references indicate that the number of occupants not as important as individual participant water usage patterns.

It should be noted that the sizing of a domestic hot water system (electric, solar, gas, etc.) is an imprecise science, and typically, general industry guidelines or rules of thumb are used to size the systems. Hot water systems are sometimes sized based upon an assumed average consumption per person per day, while other systems may be based on the physical characteristics of the house (for example, number of sinks and tubs, or number of bedrooms). With solar water heating systems, the capacity to capture heat is a function of the number and size of the solar panels, while the capacity of the storage tank determines the ability of the system to store heat. Both solar panels and storage tanks are available in discrete sizes, and the installer must choose the appropriate combination of panels and tank size to match the usage of the individual household. If a given solar system does not have either adequate number (and size) of solar panels, or adequate storage capacity, then the solar system will not provide the maximum savings. Based upon the information gathered during this pilot study, the apparent drop off in savings for the households with increased number of occupants cannot be attributed to improper system sizing.

Seasonal variations

As shown in the graph below, the average monthly savings for a solar water heating system is reduced significantly during the winter months. The reduction of savings during the winter months can be attributed to a combination of lower ambient temperatures (which enhance heat losses from the solar panels), and fewer hours of sunlight available. Another contributing factor is the practice of sizing solar water heating systems based upon summer performance. It is typical to design a solar system to produce up to 100% of hot water during the summer months, and not the winter months. If a solar system is designed to produce 100% of the hot water during the winter months, then it may collect too much heat during the summer months, leading to problems with pressure relief and dissipation of excess heat in the system. Therefore, it is common design practice for solar water heating systems to produce only a portion of the hot water needs during the winter to mitigate potential over heating problems during the summer, and the reduction in savings during winter months is expected. Another factor is that the entering water temperature in the winter may be 20° Fahrenheit or more colder than summer, requiring longer run times for the electric water heating element. Since water heaters used as backups to solar systems have only one heating element, which is placed in the upper third of the tank, an electric water heater in a solar system will have less than one half the available hot water than a conventional tank with two heating elements (top and bottom). With less available hot water in the storage tank, a solar system in the winter can have significantly longer run times on the heating element; field data verified this assumption.

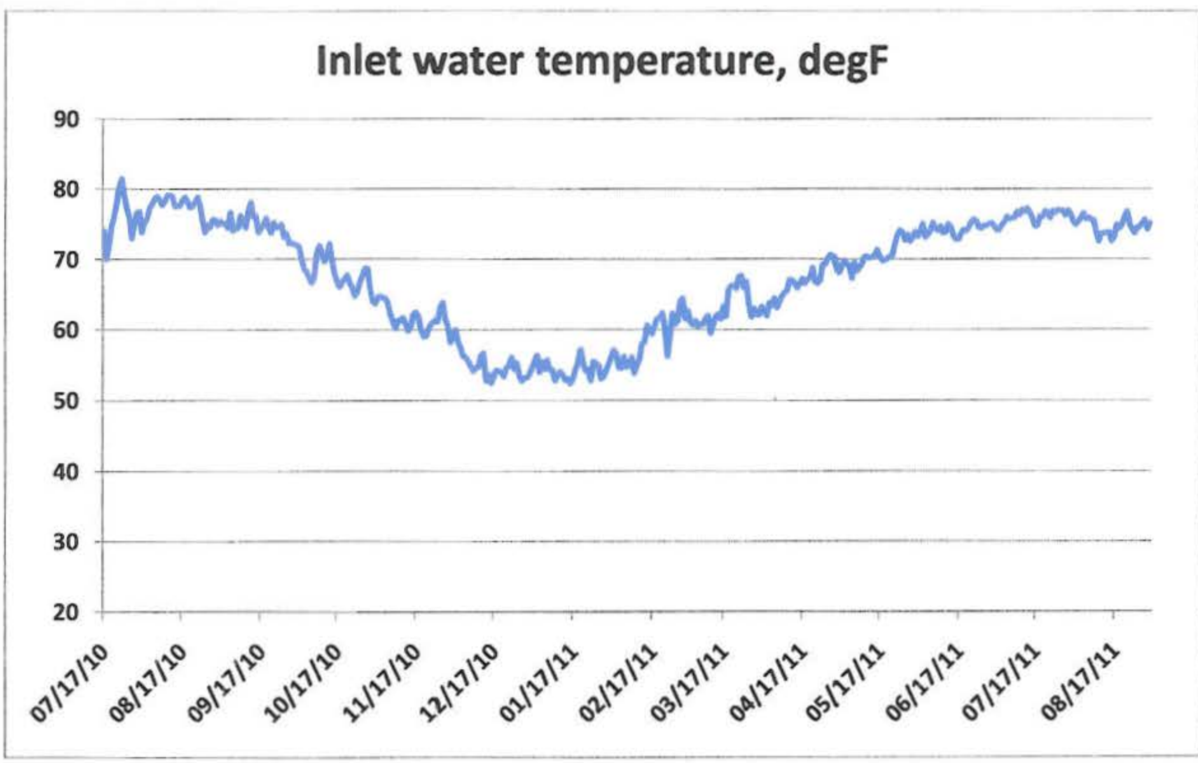


Inlet water temperature

The amount of energy it takes to heat water from a starting temperature to a higher temperature varies linearly with the temperature difference between the starting and final temperature (for example, heating a given amount of water 20 degrees takes twice the energy as heating the same water just 10 degrees). Measurements of the inlet water temperatures for selected systems were recorded, and are shown for an entire year in the graph below.

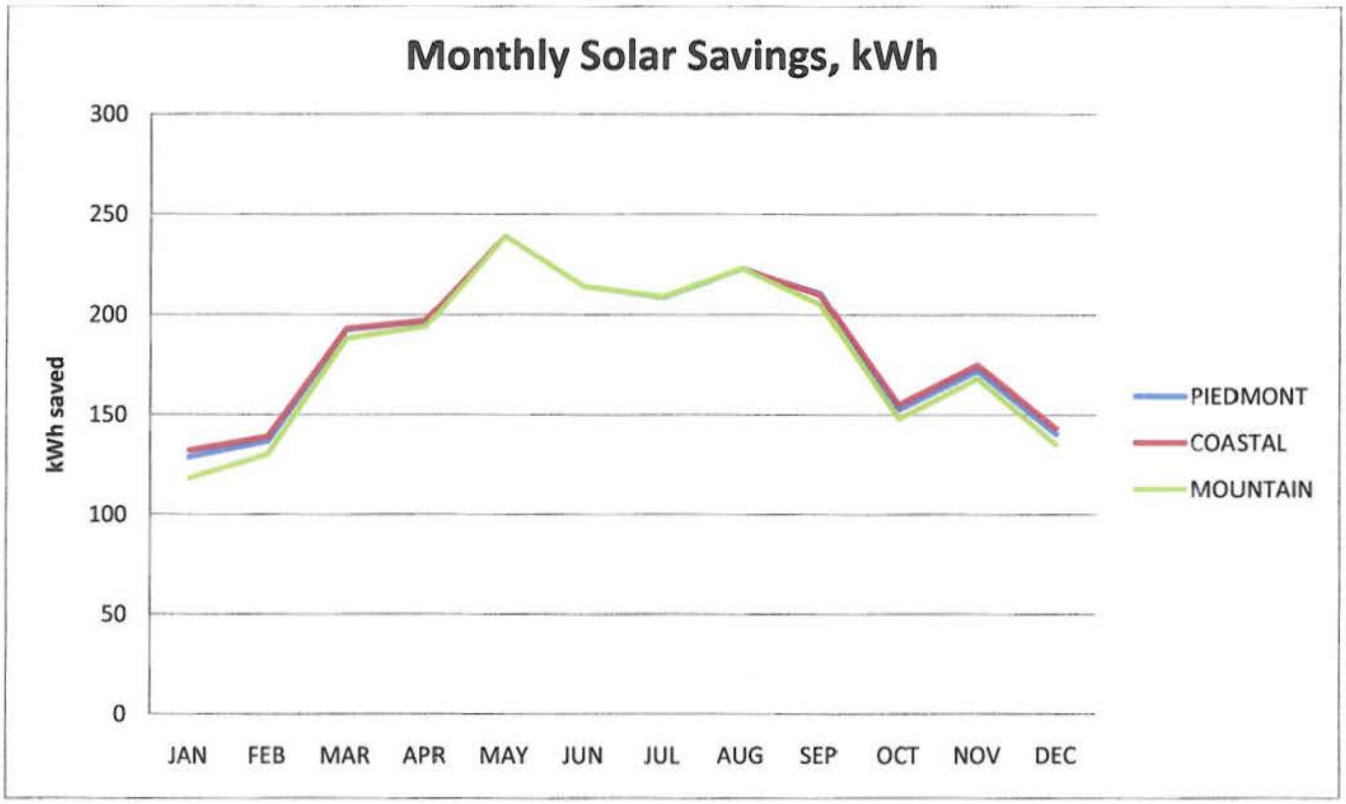
The variation in inlet water temperature from the low in winter to the high in summer is approximately 20° Fahrenheit. Although there was some minor variation in inlet water temperatures from site to site, the majority of the individual readings matched the average values very closely. Some of the systems were on deep wells, as opposed to city or town water systems, and experienced winter inlet water temperatures below 50° Fahrenheit, but the variation was not significant.

With an average 20° Fahrenheit difference between the lowest inlet water temperature in the winter versus the highest inlet water temperature in the summer, the amount of energy required to heat water from 55° Fahrenheit to 120° Fahrenheit is 44% greater than the amount of energy required to heat the same amount of water from 75° Fahrenheit to 120° Fahrenheit. Therefore, the total amount of energy required to provide a given amount of hot water, regardless of the energy source, would be significantly higher in the winter months than during the summer months.



Geographic location

Sixty households were selected for monitoring, and 20 households were chosen for three regions, Mountain (Asheville), Piedmont (Raleigh), and Coastal (Wilmington). Appendix 1, "Map of instrumented customers", to this report shows the relative geographic regions of the instrumented homes. A review of the monthly savings for each month, averaged over the homeowners within the three regions indicates not significant difference in the performance of the solar systems based upon geographical location. The chart below shows the average monthly savings by geographical region. Although the regions may experience varying weather conditions throughout the year, the monitored homes were within a given range of latitude (33.8 to 36.5 degrees), and the relative amount of sunshine available on a given day would not vary greatly from East to West.



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